Intra-Annual Changes in the Abundance of Coho, Chinook, and Chum Salmon in Puget Sound in 1997

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Introduction

Three surveys were conducted in Puget Sound during the spring, summer, and fall of 1997 (Figure 1). Using a large rope trawl designed to fish in midwater, we were able to sample surface waters for juvenile salmon as well as fish throughout the water column. The use of large rope trawls to study the marine life history of Pacific salmon is new. The large net captures fish of all sizes when a small mesh liner is used in the cod end. The work reported here is the result of only three short cruises in one year, yet there are some surprising observations. The study identified several relationships that appear to provide new information about the early life history of juvenile salmon. We think that this new information is sufficiently important to management that we are reporting it now. We believe that a continuation of the work and the testing of a new theory on the natural regulation of salmon abundance (Beamish and Mahnken 1998) will provide explanations of the factors regulating the marine carrying capacity for chinook and coho in particular and Pacific salmon in general.

Methods

Rope Trawl

When fishing to design specifications the rope trawl has an opening 21 m deep and 64.5 m wide (Beamish and Folkes 1998). In Puget Sound, we did not follow a predetermined survey design, as this was the first survey. Most sets were at the surface but other depths (15 m, 30 m, 45 m, and ≥45 m) were fished in approximate proportion to the expected relative abundance of all species of Pacific salmon. The length of sets was related to the amount of fish that were expected to be captured. We found that 1/2-hour sets produced catches that could be processed in the interval between sets or throughout the day. We were also concerned that we did not catch too many juvenile salmon. We note that the juvenile salmon populations were in the process of undergoing substantial natural mortality and our samples would be equivalent to a very small percentage of this natural mortality. During each of the three cruises, between 12 and 23 fishing sets were made in the following locations: Admiralty Inlet, Puget Sound, Possession Sound, East Passage, and Colvos Passage. Crews worked 12 hours per day during daylight. We towed the net at approximately five knots, except for deeper tows, which were possible only at four knots.

The abundance estimates used in this report are primarily an index of catch per unit effort. We wanted to emphasize the relative abundances among species during the various cruises as a general indication of the numbers of individuals. We consider that the abundance estimates are both approximate and preliminary. However, we also consider them to be minimal estimates.

Abundance

Abundance estimates were made using the catch from the volume of water fished (swept volume). We assumed that all fish in front of the opening were captured. We doubt that this is true because unpublished Russian data indicate that for a net that fished 50 m x 50 m, only 1/3 of the juvenile Pacific salmon (but larger than ocean age-0) were captured (Shuntov et al. 1988, 1993). Thus we believe that our abundance estimates are minimal, but can be used as a relative index of abundance.
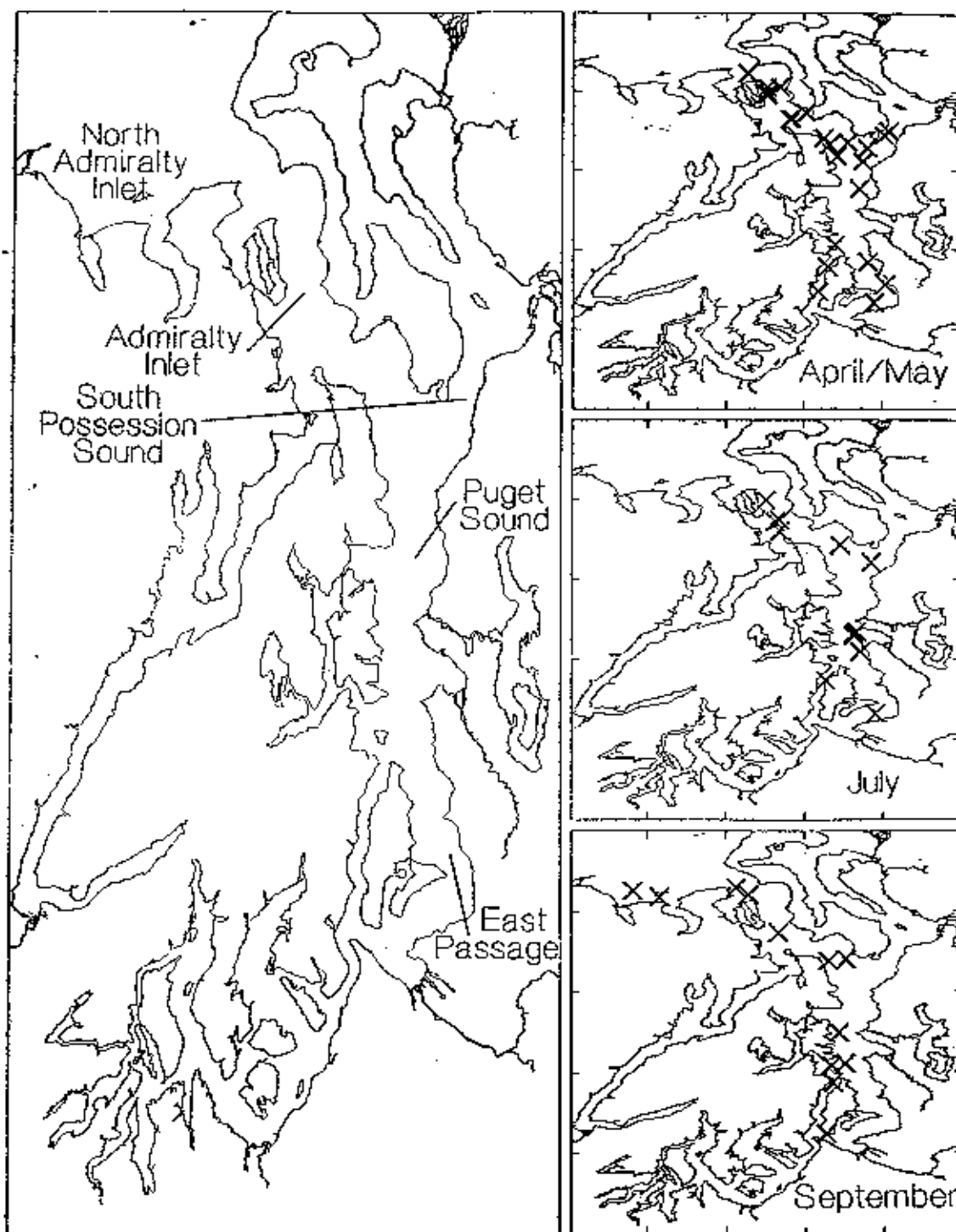
Figure 1. The five salmon management areas within Puget Sound that were surveyed (left figure), and the distribution of fishing sets (all depths shown) during each cruise (right figures). Each 'X' represents the location of one fishing set.

Abundance estimates were determined for ocean age-0 chinook, coho, and chum salmon. Only catches in the top 30 m were used, as almost all the catches were made within this depth (Figure 2). Catches with a headrope depth of 0–5 m were placed in the 0–15 m stratum, and those with a
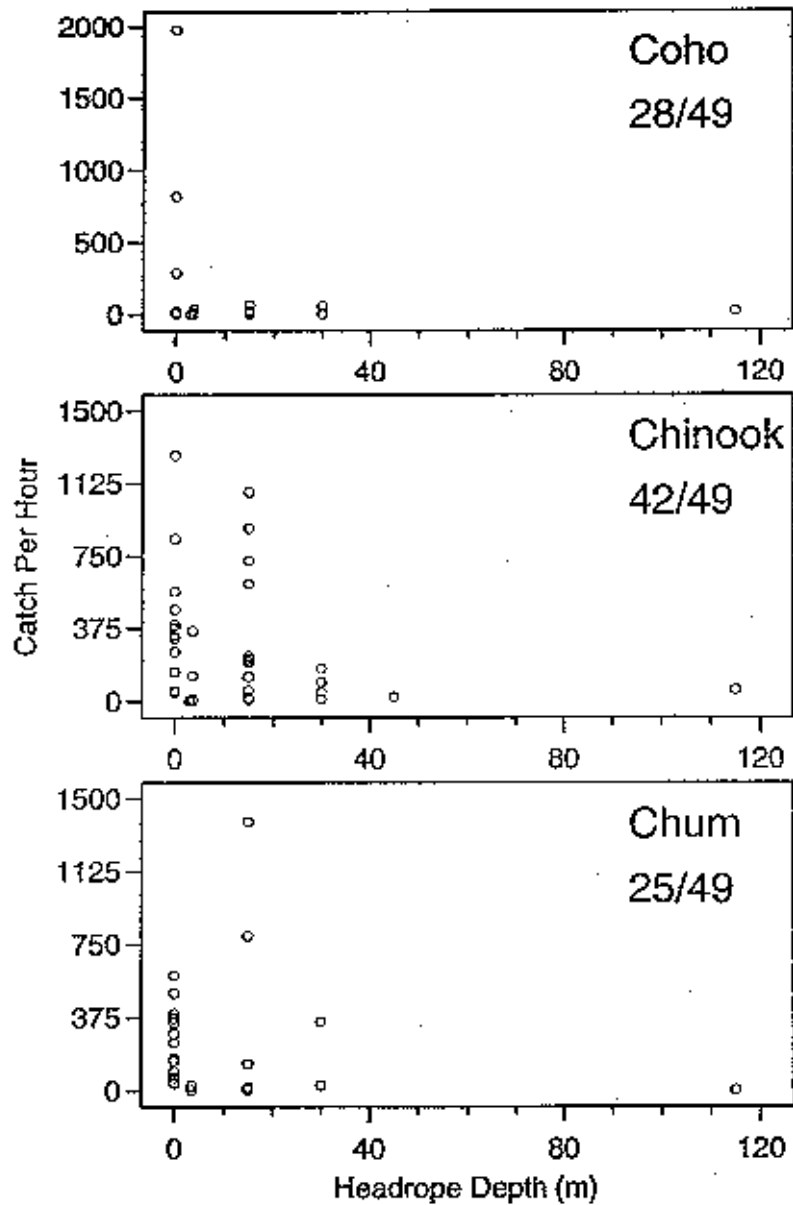
Figure 2. Catch per hour of juvenile coho, chinook, and chum salmon stratified by headrope depth. Zero catches are not shown; the ratio refers to the number of sets with catches of the species/the total number of sets.

headrope depth of 16–20 m in the 16–30 m stratum. There were no sets with headrope depths 6–15 m or 17–30 m. Abundance was estimated using the volume strained for each set, dividing the total volume of that stratum in Puget Sound by this volume and multiplying by the catch. The abundances estimated for each set were then averaged, and the estimates from the two strata were added together. The area of Puget Sound is 2330 km^2 (Thomson 1994). Confidence limits were determined for each estimate, but were so large (frequently ranging from a value of 0 to 2 or 3 times the estimate) that they have not been reported.

All salmon were examined for missing fins and coded wire tags (CWT), and most salmon were measured for fork length. Randomly selected samples were examined for stomach content and otoliths were removed.

The identification of juvenile salmon is not a trivial matter. Common criteria involving color and general appearance can cause problems. We used measurements, counts, and otolith shape to ensure that identifications were accurate. Chinook and coho were readily separated from pink, chum, and sockeye juveniles by the presence of spots on the body, the size and spacing of gill rakers, the number of branchiostegal rays, and otolith size. The chinook otolith is approximately two times larger than a coho otolith and is an excellent character for separating these species. Pink, chum, and sockeye were separated using gill raker number, length and spacing, scale size and number, and body markings. A useful character is the longer length of the intestine of chum salmon relative to pink and sockeye.

Results

Catches

In this report we summarize the catches of salmon (Pacific and Atlantic) and report the results of our studies of the three dominant species of Pacific salmon: coho (*Oncorhynchus kisutch*), chinook, (*O. tshawytscha*), and chum (*O. keta*). Catches of non-salmon species will be reported elsewhere. The set distances for each of the three cruises (Figure 1) were approximately 5.1 km. There were 49 sets completed in the three cruises, 49% in the 0–15 m depth interval, 31% in the 16–30 m interval, 8% in the 31–45 m interval, and 12% deeper than 45 m (Table 1). Chinook and chum were the most abundant salmon in the catches, followed by coho (Table 2). There were small catches of juvenile pink, sockeye, and steelhead, and of two Atlantic salmon that had escaped from net pens. We separated catches into juveniles with an ocean age of zero and those with an ocean age of one year (one winter annulus) or greater. In this report, lengths were used to partition fish into the two age groups. This method works well for all species except chinook in April/May and July. For chinook, for these cruises, we defined ocean age-0 fish as ≤100mm in April/May and ≤190mm in July. A sample of 91 selected fish was aged from the smallest length frequency distributions in April/May. Four of the 91 were stream type with an ocean age of zero. For this report, these fish were not included as ocean age-0 fish and are included in the ocean age-1 category.

Table 1. Number of sets for the specified headrope depth range for each cruise.

Headrope Depth (m)	April 14 and May 1, 2	July 9, 10	Sept. 23, 24	Total
0-15	10	7	7	24
16-30	7	4	4	15
31-45	2	1	1	4
≥45	4	2	0	6
Total	23	14	12	

In April/May, virtually all the chinook were in the ocean age-1 category. A small number of ocean ages greater than one were also captured. The catch of coho was very small, indicating that few coho from the previous year were in the Sound, and that only a few of the smolts that would enter the ocean in 1997 had entered the areas fishable by our net. There were only six chum caught, all of which had entered salt water in the previous year (Table 2), indicating that juvenile chum that entered the Sound in 1996 probably left during the winter. In July, there were relatively large catches of ocean age-0 chinook and coho. Catches of chinook older than ocean age-0 were substantially reduced from April/May (Table 2). Juvenile chum catches were about 2/3 the size of the coho catch. A few juvenile and adult pink and sockeye were captured along with two Atlantic salmon that had clearly escaped from net pens, as their caudal fins were damaged and their gonads were deformed.

Table 2. Catch (numbers), average catch per hour (CPUE)[1], and standard deviations (SD) of salmon, 1997.

Species		April/May			July			September		
		Catch	CPUE	SD	Catch	CPUE	SD	Catch	CPUE	SD
Coho	ocean age-0	10	0.5	1.6	1696	282.5	580.7	38	7.3	8.8
	≥ocean age-1	26	1.5	3.1	2	0.3	0.8	15	2.5	4.6
Chinook	ocean age-0	2[2]	0.1	0.4	3189[3]	530.8	342.3	1545	282.4	255.4
	≥ocean age-1	495	28.7	40.0	93	16.1	28.7	19	3.3	6.4
Chum	ocean age-0	-	-	-	1063	177.6	213.8	2999	593.7	919.8
	≥ocean age-1	6	0.3	1.0	-	-	-	-	-	-
Pink	ocean age-0	-	-	-	4	0.7	1.3	-	-	-
	≥ocean age-1	1	0.1	0.2	1	0.2	0.6	-	-	-
Sockeye	ocean age-0	3	0.2	0.6	4	0.7	1.3	-	-	-
	≥ocean age-1	-	-	-	1	0.2	0.6	-	-	-
Steelhead	ocean age-0	9	0.5	2.1	-	-	-	-	-	-
	≥ocean age-1	-	-	-	-	-	-	-	-	-
Atlantic	ocean age-0	-	-	-	-	-	-	-	-	-
	≥ocean age-1	1	0.1	0.2	2	0.2	0.6	-	-	-

[1] CPUE includes all sets, with a headrope depth of ≤45 m, total catch includes all sets. A dash indicates no catch.
[2] Ocean age-0 is defined as ≤100 mm.
[3] Defined as 80 to 190 mm, (57% that were not measured were assumed to have the same age composition as those measured for fork length.

By September, catches of juvenile coho decreased dramatically compared to July. Only a few maturing coho that entered salt water in the previous year were found. There was an astonishing increase (3.4 times) in juvenile chum catches, which was equivalent to almost double the coho catch in July. Juvenile chinook catches declined by about 1/2 compared to June/July. No other salmon were captured in September, and catches of non-salmon species (not reported here) were almost zero (except for sandlance and age-0 herring). In all cruises, chinook, chum, and coho juveniles tended to be distributed throughout Puget Sound, however the greatest concentrations were in the Admiralty Inlet Area (Salmon Management Area 9).

Lengths

As mentioned previously, the samples of chinook captured in April/May have not been aged. A stratified sample of five fish from each cm-length class (n=91) indicated that between the lengths 80 mm and 350 mm, most (93%) were ocean age-1. There were two ocean age-0 chinook that had entered the Sound in 1997 (85 mm, 92 mm), and there were four that were stream-type chinook that had spent one winter in fresh water and thus were also ocean age-0, but larger. For abundance estimates only, we classified all chinook ≤190 mm from the April cruise as ocean age-1. The average lengths of the ocean age-1 chinook in April/May and ocean age-0 chinook in July and September were 249 mm, 129 mm, and 164 mm respectively (Table 3). (The unmeasured chinook in July [57%] were assumed to have the same fork length distributions as the measured percentage).

Table 3. Average fork lengths (mm) and standard deviations (SD) of Pacific salmon caught in Puget Sound in 1997. A dash indicates no data.

	Ocean Age	April/May			July			September		
		mm	(SD)	n	mm	(SD)	n	mm	(SD)	n
Coho	0	137	(21)	10	208	(25)	849	259	(25)	38
	1	331	(35)	26	444	(24)	2	489	(43)	15
Chinook	0	89	(2)	2	129	(19)	1381	164	(27)	1079
	≥1	249	(114)	495	323	(144)	40	390	(116)	19
Chum	0	-		-	139	(17)	504	179	(15)	1017
	≥1	311	(61)	6	-		-	-		-

In April, there were small numbers of coho that were ocean age-1 and had an average length of 331 mm (Table 3). These coho were not present in the catches in June/July, but reappeared in September. Ocean age-0 coho were present in small numbers in April at an average length of 137 mm (Table 3). This age group was abundant in June/July, with an average length of 208 mm. By September, the few age-0 coho that remained had an average fork length of 259 mm. There was some indication that coho in south Puget Sound were smaller than those in the north (data not shown).

In July, the ocean age-0 chum had a mean fork length of 139 mm (Table 3) and by September, the mean length was 179 mm. The shape of the frequency distributions also changed from negatively skewed in June/July to positively skewed in September.

Index of Abundance

The abundance estimates for chinook, coho, and chum were made for the headrope depths from 0 to 30 m, and they are believed to be indices of minimal abundance. There were small catches below these depth strata (Figure 2), which were not included in the estimates. The omission of these catches is not considered to be an important error, because the largest error probably is our overestimate of catchability. In April/May, there were few ocean age-0 coho, chum, or chinook, consequently, the abundance estimates were extremely low. In July, all three species were abundant as ocean age-0 juveniles. There were very large estimates of chinook of 5.4 and 5.5 million in each stratum, totaling 10.9 million (Table 4). Coho were the second most abundant Pacific salmon in the catches at this time. Virtually all (91%) of the estimated 4.7 million coho were in the top 15 m. Chum were also concentrated in the top 15 m, with a total abundance of 2.86 million.

In September, the abundance index estimate of coho decreased to 180,000 fish. At the same time, the abundance index of chum increased almost four times to 13.9 million. Chinook salmon abundance remained high, but declined to 6.2 million (Table 4).

Table 4. Abundance estimates of ocean age-0 Pacific salmon in Puget Sound in 1997.

		April/May	July	September
Coho	0–15 m	12,300	4,300,000	40,000
	16–30 m	0	400,000	140,000
	Total	12,300	4,700,000	180,000
Chum	0–15 m	0	2,500,000	1,900,000
	16–30 m	0	360,000	12,000,000
	Total	0	2,860,000	13,900,000
Chinook	0–15 m	2,600	5,400,000	1,800,000
	16–30 m	0	5,500,000	4,400,000
	Total	2,600	10,900,000	6,200,000

We emphasize again that the abundance estimates are not believed to be true estimates of population size. They are, however, believed to be representative of relative abundance. We doubt that the assumed catchability of one is correct, which means that our abundance estimates are low. The index of abundance could be replaced by catch per unit effort (CPUE), which is an indication of abundance changes, because the changes are so large. Thus the dramatic change in coho abundance is probably real. The dramatic increase in chum abundance is also believed to be real. The increases in chum abundances from July to September probably represent movements from nearshore areas into the areas that were accessible by our vessel, the *W.E. Ricker*.

Coded-Wire Tag (CWT) Recoveries

All salmon were examined for missing fins. In addition to the samples collected in Puget Sound, we report the tagging location of coho released into Puget Sound in 1997 and captured in the Strait of Georgia, Juan de Fuca Strait, and off the west coast of Vancouver Island in October 1997 (Table 5). In June/July, there were adipose-clipped coho that we were unable to sample because we had technical problems with the CWT detector. Consequently, when sampling the two largest catches, all coho missing an adipose fin were taken back to the laboratory for processing (Table 6). In the two samples from July, in one set (n=988), 16% of the fish had an adipose fin missing and 18% of these fish had a CWT (Table 6). In the second set (n=408), 19% had a missing adipose fin, 27% of which had a CWT. In the April/May, and September cruises, all coho with a CWT were sampled.

Table 5. Recaptures of coded wire tagged (CWT) coho released into Puget Sound in 1997 for each brood year (BY).

In Puget Sound[1]						
April/May		July		September		
BY 95	BY 94	BY 95	BY 96	BY 94	BY 95	BY 96
Hatchery 1	0	60	11	1	1	0
Wild 0	0	8	0	0	0	0

[1] No Canadian CWT's found in Puget Sound

In the Strait of Georgia		
June/July	September	October
BY 95	BY 95	BY 95
Hatchery 4	9	1
Wild 0	1	0

In Juan de Fuca Strait								
February		April	May		June/July		September	
BY 94	BY 95	BY 94	BY 94	BY 94	BY 95	BY 96	BY 95	BY 96
Hatchery 17	1	18	11	8	11	1	1	1
Wild 0	1	3	0	3	1	0	0	0

Off the west coast					
April	May/June	July		October	
BY 94	BY 94	BY 94	BY 95	BY 95	BY 96
Hatchery 16	2	9	7	14	1
Wild 0	0	0	1	2	0

Table 6. Number of coho with missing adipose fins captured during the survey in Puget Sound.

Cruise	Total Number of Age-0 coho	Adipose fins missing	Number examined for CWT	Number of CWT's
April/May	10	3	3	2
July	1696	295	254	63
September	36	3	3	3

In Juan de Fuca Strait, ocean age-1, hatchery coho from Puget Sound were recaptured in February, April, and May. One coho from the 1995 brood year was recaptured in February. Releases in 1997 were recaptured in June/July and September. Off the west coast, the 1997 releases were recaptured in July and October (Table 5). No coho with CWT's from Canadian hatcheries were recaptured in Puget Sound, although one coho with a left pelvic clip was found in September. It is apparent that coho from Puget Sound moved out of the Sound and into the Strait of Georgia, Juan de Fuca Strait and off the west coast as early as July.

We captured a large number (119) of CWT chinook in Puget Sound in July that were from the 1996 brood year and released into the Sound in 1997 (Table 7). Most tags were from the Hupp Springs (24) and Grovers Creek (22) facilities. Large returns were also from Soos Creek (15), Washington Department of Fish and Wildlife (16) and Nisqually (16) releases. These releases were also abundant in the September catches. Catches of chinook from the 1996 brood year (1997 year of ocean entry) outside of Puget Sound were not large (Table 8), relative to previous year's releases and to coho recoveries. Although it is difficult to interpret tag recovery data, we propose that the CWT results for chinook indicate that fewer chinook were moving out of Puget Sound in the summer. This is consistent with our observation of a relatively large abundance of chinook in Puget Sound in September.

Table 7. Number of chinook with missing adipose fins captured during the survey.

Cruise	Total Number of Age-0 chinook	Adipose fins missing	Number examined for CWT	Number of CWT
April/May	2	0	2	0
July	3251	150	150	128
September	1559	74	74	74

Table 8. Recaptures of coded wire tagged (CWT) chinook, released into Puget Sound in 1997 for each brood year (BY).

	In Puget Sound						
	April		July			September	
	BY 94	BY 95	BY 94	BY 95	BY 96	BY 95	BY 96
Hatchery	3	63	1	6	119	11	61

	In the Strait of Georgia					
	April		May/June	July		October
	BY 94	BY 95	BY 95	BY 94	BY 95	-
Hatchery	10	2	3	2	3	0

	In Juan de Fuca Strait						
	February	April		May/June		July	September	October
	BY 95	BY 94	BY 95	BY 94	BY 95	BY 96	BY 96	-
Hatchery	11	3	4	4	6	1	2	0

Table 8 (continued). Recaptures of coded wire tagged (CWT) chinook, released into Puget Sound in 1997 for each brood year (BY).

| | Off the west coast | | | | | | |
| | April | | May/June | | July | October | |
	BY 94	BY 95	BY 94	BY 95	BY 96	BY 94	BY 96
Hatchery	11	5	1	2	1	1	1

Stomach Content Analysis

In the three cruises, a total of 1004 stomachs from the combined coho, chum, and chinook samples were examined (Table 9). The volume of the stomach contents was estimated and washed into a small tray where the contents were identified using a 10x magnifying glass. All samples were from ocean age-0 fish, except the April chinook samples, which were defined to be ocean age-1 as described earlier. All contents were determined by a person with extensive experience identifying marine plankton.

In general, the major food items of coho and chum were similar, but varied among cruises. In April/May, euphausids dominated the diets of all three species. In July, coho and chum fed heavily on crab larvae (Table 9). For chum, the predominant stomach item appeared to be mostly digested crab larva. In September, amphipods were the dominant item in the stomachs of coho and chum. There were differences among the less important food items. After April, 1/5 of the coho diet of was fish, while chum did not feed on fish. About 1/5 of the chum diet was classified as miscellaneous species that were not consumed by coho or chinook. Chinook fed much more on fishes than the other two species. The other key items in their diet were similar to major items consumed by coho and chum.

Table 9. Stomach contents as a percentage of the total volume from all samples.[1]

| | April/May | | | July | | | September | | |
Item	coho	chum	chinook	coho	chum	chinook	coho	chum	chinook
Euphausiids	92.7	100	67	0.5	0	6.8	8.6	5.1	3.5
Amphipod	2.2	0	0.6	0.4	0.7	1.6	60.0	47.2	9.7
Crab larva	0.7	0	0	76.3	32.2	19.4	12.4	5.6	12.2
Fish remains	0.3	0	31.4	22.1	0	68.4	17.4	0	71
Digested	3.9	0	0.4	0	35.8	1.2	1.2	17.8	0.6
Copepod	0	0	0.1	0	12.1	0.7	0	0.5	0.3
Miscellaneous[2]	0	0	0	0	18.4	0	0	23	0
Number examined	10	4	336	149	19	124	38	120	204
Number empty	0	0	26	15	6	15	6	16	34
Avg. volume of fish with contents (cc)	0.7	1.6	3.9	2.6	0.1	0.8	2.0	0.4	1.0

[1]Total percentages may not add up to 100% as some minor food items are not listed.
[2]Miscellaneous includes: chaetognath, *Oikopleura*, ctenophore.

Condition Factors

Condition factors were calculated as the weight (g) x 100 divided by the length (cm) cubed, and averaged for each species for the July and September cruises. Condition factors remained about the same among cruises for chinook and chum. The condition of coho decreased from July to September (Table 10), although this difference was not significant ($p > 0.05$).

Table 10. Condition factor $^W/_L{}^3$ x 100 and standard deviation (SD) for ocean age-0 Pacific salmon. Averages of lengths and weights are for fish used to measure condition factors.

Species	Date	Average Fork Length (mm)	Average Weight (g)	Average Condition Factor	S.D	n
Chinook	July 1997	135	30	1.124	0.168	249
	Sept. 1997	168	62	1.149	0.159	257
Coho	July 1997	211	126	1.313	0.387	167
	Sept. 1997	259	223	1.245	0.114	38
Chum	July 1997	146	32	1.010	0.140	19
	Sept. 1997	183	63	1.005	0.069	120

Discussion

Our study of Pacific salmon in Puget Sound involved collecting a relatively few samples three times in one year. Thus, our conclusions need to be considered as information that improves our understanding of some aspects of the marine life history of Pacific salmon and raises more questions about other aspects. The study in Puget Sound was part of a larger study of the factors that regulate the abundance of coho and chinook in the ocean.

In the Strait of Georgia, coho do not leave until the late fall. Thus, it was unexpected to observe the disappearance of coho from the Puget Sound catches by September. The associated large increase in juvenile chum salmon catches was similar to the changes that occur in the fall in the Strait of Georgia (Beamish and Folkes 1998), except that coho do not leave until later in the Strait of Georgia (Beamish et al. 1998a). The abundance of chum relative to coho in Puget Sound increased from 1.6 times lower in June/July to 82 times higher in September. The catches of CWT-tagged juvenile coho in Juan de Fuca Strait in June/July and off Vancouver Island in November indicated that coho probably left Puget Sound and moved offshore throughout the summer. We observed that about 15% of the coho in the Strait of Georgia in September were from Puget Sound. Because our abundance estimates of coho in the Strait of Georgia in September 1997 were lower than for Puget Sound in July, (Beamish et al. 1998a), we think that most of the Puget Sound coho moved into Juan de Fuca Strait and not into the Strait of Georgia.

Coho and chum salmon fed on similar items and were similar in size. Thus, it was possible that the movement of juvenile chum salmon from the nearshore areas into the open water of the Sound (where they are vulnerable to our nets) was associated with the movement of coho out of the Sound. If we compare our estimate of 5.7 million juvenile coho in June/July with the estimated production of 14 million hatchery smolts and 6 million natural smolts (WDFW 1998), it may appear that about 75% of the smolts died by June/July. However, we stress again that the estimate of 5.7 million is only a relative estimate at this time. Certainly by September there were less than 1% of the coho that entered the Sound earlier in the year. The size of coho and the condition of coho in Puget Sound in June/July is larger and better than observed for coho in the Strait of Georgia ($\overline{FL} = 174\,mm; \overline{CF} = 1.14$), however there was evidence that the condition of coho in Puget Sound declined by September.

It is an important observation that large numbers of chum and chinook remained in Puget Sound until at least September without a change in their condition factor. This indicates that food was available for these species and presumably in abundance, because there were large numbers feeding and there was no evidence of starvation. Coho therefore may have left the Sound for reasons associated with the behaviour of chum. The concept of crowding of coho could lead to a reduction in appetite and in growth rate. A reduced rate of growth could be a stimulus to leave the area. Although the reason or reasons remain unknown, it is possible that the movement out of Puget Sound in the late summer and out of the Strait of Georgia in the late fall may have some common causes. In the Strait of Georgia, movement out of the Strait has been associated with ocean and climate conditions (Beamish et al. 1994; Beamish et al. 1998b). There also has been a change in the behaviour of juvenile chum salmon in the Strait of Georgia resulting in large abundances relative to coho remaining in the

Strait of Georgia in the fall (Beamish and Folkes 1998). Although the abundances are not as large as in Puget Sound, there is a similarity in the behavior of chum. It is possible that the movement of coho out of the Strait of Georgia is also influenced by the accumulation of juvenile chum in the coho feeding areas in the fall. If there is an association, there may be opportunities to influence both coho behavior and marine survival. It would be interesting to learn whether there is any relationship between the large numbers of chum that remain in the Strait of Georgia later in the year than in the past (Beamish and Folkes 1998) and those found in Puget Sound in September. Techniques are available to answer many of the questions resulting from this study.

The large abundance late in the year relative to the final returns is an indication that we need to know more about the factors regulating carrying capacity. Thus, the view that final abundance is determined shortly after entering the ocean is not consistent with our observations. Why do coho leave so early in the year, and does this movement contribute to higher levels of marine mortality according to the mechanisms proposed by Beamish and Mahnken (1998)? Although we cannot control the natural changes in the ocean ecosystem, we do have control over the number of smolts that compete in this ecosystem, and we need to know whether a reduction in releases could improve the marine survival of naturally spawning coho.

Acknowledgments

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